

Full Length Research Paper

Phytotoxicity of compost and uncompost poultry manure

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Different uncomposted and composted poultry manure types (laying hen and broiler), mixed at increasing rates (0, 25, 50, 75 and 100%) with two amended peat substrates, were tested to study the phytotoxicity using the cress (*Lepidium sativum*, L.) germination method. The results showed that composting generally reduced the phytotoxicity of the manure mixtures. The germination index was highest in both amended peat substrates. When the peat substrates were mixed with uncomposted poultry manure, only the rate of 25% of uncomposted poultry manure from laying hens showed reduced toxicity. These was not phytotoxicity when the poultry manure was composted in rates of 25, 50 and 75% of deep-pit manure from laying hens and in rates of 25 - 50% of the poultry manures from stock piled, deep litter and broiler litter in mixtures with both peat substrates.

Key words: Uncomposted poultry manure, composted poultry manure, phytotoxicity, germination index, ammonia concentration, electrical conductivity.

INTRODUCTION

Animal manures have been effectively used as fertilizers for centuries. Poultry manure, for centuries, has been recognized as perhaps the most desirable of these natural fertilizers because of its high nitrogen content. In addition, manures supply other essential plant nutrients and serve as a soil amendment by adding organic matter (Sloan et al., 2003).

Intensive poultry farming may, however, be detrimental to the environment due to the need to dispose of the great amounts of excrements produced and due to the unstable nature of raw poultry manure. Waste by-products generated by the worldwide annual production of more than 40 million metric tons of poultry meat and 600 billion eggs are generally applied to agricultural fields as the final step of a producer's waste management strategy. Application of unstable uncomposted poultry manure may be phytotoxic to plants and cause slow plant growth or crop damage due to insufficient biodegradation of the organic matter. Under average land application conditions, the nutrients in poultry manures are in excess of

the crops' utilization potential, which causes, especially, when utilized under poor management conditions, nutrient losses to the environment. The organic nitrogen from animal manure can be changed to ammonia gas (NH₃) called ammonia volatilization. The ammonia volatilization causes a net loss of nitrogen from soil systems (Mattsson, 1998; Williams et al., 1999).

Composting has become a preferred method for municipalities and industries to recycle a variety of organic by-products in order to apply them as soil conditioners and amendments (Butler et al., 2001). One of the most important factors, affecting the successful use of poultry manure compost for agricultural purposes, is its stability and maturity. If unstable or immature compost is applied, it can induce anaerobic conditions, in the same way as the microorganisms utilize O₂ in the soil pores to break down the material (Mathur et al., 1993). Another problem associated with the application of immature compost is the release of phytotoxic compounds during the composting process (Hue and Liu, 1995).

The terms 'stability' and 'maturity' are both commonly used to define the degree of decomposition of organic matter during the composting process even being conceptually different. Compost stability refers to the level of

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of activity of the microbial biomass which can be determined by O₂ uptake rate, CO₂ production rate or by the heat released as a result of microbial activity (Iannotti et al., 1994; Conti et al., 1997). Compost maturity refers to the degree of decomposition of phytotoxic organic substances produced during the active composting stage (Wu et al., 2000).

The objective of this work was to evaluate the effect of water extracts from different mixtures of composted and uncomposted poultry manures (laying hens and broilers) with two amended peat substrates in the germination process and root growth of cress (*Lepidium sativum*, L.) in order to determine their phytotoxicity.

MATERIALS AND METHODS

Materials

The study was conducted at the National Institute for Agricultural Research in Madrid, Spain. Thirty treatments with rising rates (0, 25, 50, 75 and 100%) of two sources of poultry manure (laying hens and broilers), in mixtures with two amended peat substrates were tested (Table 1). The manures were collected from farms located in Castillay León (Spain).

The amended peat substrate 1 was a commercial substrate COMPO SANA[®] which consisted of black peat and added nutrients. The amended peat substrate 2 was a sphagnum peat from the Baltic regions, fertilized to suit the requirements of demanding plants. Samples of laying hen manure, from different places and facilities were collected: stock piled litter from Tordomar (Burgos) and deep-pit litter (the manure is in the open storage under the cages on conveyor belt) from Megeces (Valladolid).

In the stock piled litter system, the manure was stored in piles. The stock piled litter house was ventilated and heated to maintain a stable temperature inside the stalls. Sometimes an open scraper was applied to remove the manure from under the cages to an open storage in a different place. In the deep-pit system, manure was stored in pits of 250 cm depth approximately. In the deep pit warehouse, the manure was ventilated with the air flow that crosses the warehouse. There is a fans system that produces the ventilation air flow. Due to this flow of warm air, the manure that was stored in the pit is dried.

Finally, in the deep litter system, the manure was in an open storage under the cages and on top of the conveyor belt. The air movement and its replacement, was made by natural ventilation. Broiler litter samples were collected from Cogeces del Monte (Valladolid). Broiler litter is a mixture of chicken excreta, bedding, and other materials generated during broiler production (e.g., soil, feathers, insects, remaining food, water, etc.). Bedding material is used to absorb droppings and to facilitate removal of excreta. Broiler growing period is about 45 days long, at the end of each period, broiler litter including bedding material, was removed and replaced by fresh bedding material. The broiler bedding material consisted of wheat and barley straw.

The samples of uncomposted manure were placed in polyethylene bags, packed with ice, in a cooler bag and were sent to the laboratory, the same day, for their chemical analysis (Soil Conservation Service, 1992). Another experiment was carried out to study the effect of composted manures on cress germination and root growth. In order to do that, samples of the same manures (Table 1) were composted (indoor) for 90 days in piles of 1 m width, 1 m length and 0.2 m height. The piles were turned over every 15 days in order to improve the O₂ level inside the pile and the homo-

geneity of material for chemical analysis (Tomati et al., 2000), and were periodically watered. Temperature and water content of the composts were recorded weekly (Flynn et al., 1995; Zubillaga and Lavado, 2006). The highest temperature reached was 70°C for a week approximately, and then the compost reached its maturity.

After 90 days, about 1 kg of sample was formed from a mixture of five single samples taken from five different points along the pile. Compost samples were taken from the top to the bottom of the pile then they were put in polyethylene bags and transferred to the laboratory at the same day.

Germination test

A modified phytotoxicity test, based on the germination bioassay with seeds of cress (*L. sativum* L.), developed by Zucconi et al. (1981) was carried out. Manures extracts (ten replicates for each mixtures of composted or uncomposted poultry manure with all substrates at different rates from the two peat) were obtained shaking 10 g of manure with 100 ml distilled water for 15 h at room temperature in the dark. The flasks (10,000 g) were centrifuged for 20 min and the supernatant filtrated through the Whatman N^o 1 paper filter. Ten seeds of cress (*L. sativum* L.) were placed in a 9 cm diameter petri dishes lined with filter paper (Whatman # 3) containing 5 ml of each extract. Petri dishes with filter paper and 5 ml of distilled water served as control. The petri dishes were sealed with parafilm to minimize water loss while allowing air penetration and then they were placed in an incubator at a constant temperature and humidity suitable for their germination. The test procedure is summarized in Table 2. Seed germination and the length of the longest root produced by the seeds were measured after 48 h in all the extracts and they were compared with those of the water control. The germination index (GI) was obtained by multiplying germination (G) and relative root growth (RRG), both expressed as percentage (%) of control values. This index has proven to be the most sensitive parameter, capable of detecting low levels of toxicity which affect root growth, as well as high toxicity levels which affect the germination (Tiquia and Tam, 1998).

$$GI = (G\% \times RRG\%) \times 100,$$

where,

$$G\% = (\text{number of seeds germinated in sample} / \text{number of seeds germinated in control}) \times 100$$

$$RRG\% = (\text{mean root length in sample} / \text{mean root length in control}) \times 100$$

Chemical analyses

Chemical analyses were carried out on uncomposted and composted poultry manure samples (Table 3 and Table 4, respectively) and on the two amended peat substrates. The following parameters were determined: pH was measured in a 1:2.5 (w/v), substrate water suspension with a glass electrode (pHmeter BASIC20). The electrical conductivity was determined in a 1:5.0 (w/v), substrate: water suspension with a platinum electrode connected to a conductivimeter (CDM3 Radiometer, Copenhagen) at a reference temperature of 25°C. Organic oxidizable carbon was analysed by the Walkley and Black method (APHA, AWWA, WPCF, 1998). Total Kjeldahl nitrogen was determined by the Kjeldahl method (Hesse, 1971) and inorganic nitrogen (NH₄⁺-N and NO₃⁻-N) by the Bremner method, using airstream distillation (Bremner, 1965). P, K, Ca and the heavy metals Cu, Zn, Pb, Ni, Cr and Cd were extracted with acids (McGrath and Cubliffe, 1985) and their concentrations determined using inductively coupled argon plasma emission spectrometry (ICPES) (Sims and Kline, 1991).

Table 1. Treatments of poultry manure (uncomposted and composted) with amended peat substrates 1 and 2.

Treatments	Broiler (%)	Laying hen Stock piled (%)	Laying hen Deep pit (%)	Laying hen Deep litter (%)	Peat substrate 1 (%)	Peat substrate 2 (%)
T1	0	0	0	0	100	0
T2	25	0	0	0	75	0
T3	50	0	0	0	50	0
T4	75	0	0	0	25	0
T5	0	25	0	0	75	0
T6	0	50	0	0	50	0
T7	0	75	0	0	25	0
T8	0	0	25	0	75	0
T9	0	0	50	0	50	0
T10	0	0	75	0	25	0
T11	0	0	0	25	75	0
T12	0	0	0	50	50	0
T13	0	0	0	75	25	0
T14	0	0	0	0	0	100
T15	25	0	0	0	0	75
T16	50	0	0	0	0	50
T17	75	0	0	0	0	25
T18	0	25	0	0	0	75
T19	0	50	0	0	0	50
T20	0	75	0	0	0	25
T21	0	0	25	0	0	75
T22	0	0	50	0	0	50
T23	0	0	75	0	0	25
T24	0	0	0	25	0	75
T25	0	0	0	50	0	50
T26	0	0	0	75	0	25
T27	100	0	0	0	0	0
T28	0	100	0	0	0	0
T29	0	0	100	0	0	0
T30	0	0	0	100	0	0

Table 2. Summary of seed germination test conditions.

Test conditions	
Test type	Static
Pre-treatment	No
Temperature	25°C
Humidity	40 - 50%
Light	No
Test vessel	9 cm diameter culture dish, Whatman No. 3 filter paper
Test volume	5 ml/dish
N° seeds	10/dish
Replicate	10
Control	Distillate water
Test duration	48 h

Table 3. Chemical composition of amended peat substrates and uncomposted laying hen and broiler manures. Standard deviations are in parentheses.

Chemical composition	Broiler	Laying hen Stock piled	Laying hen Deep pit	Laying hen Deep litter	Peat Substrate 1	Peat Substrate 2
NH ₄ ⁺ -N (mg kg ⁻¹)	10409.26 (3.92)	30293.17 (1.08)	6151.31 (1.71)	9651.89 (3.91)	58.93 (1.39)	61.26 (1.38)
NO ₃ ⁻ -N (mg kg ⁻¹)	219.65 (1.77)	601.72 (3.91)	96.09 (1.39)	82.37 (1.14)	1602.82 (1.05)	1311.58 (1.70)
Kjeldahl nitrogen (%)	4.21 (1.04)	4.78 (0.50)	3.24 (1.53)	4.30 (0.50)	0.98 (0.33)	1.14 (0.34)
pH (H ₂ O)	8.32 (0.45)	8.24 (0.57)	8.52 (0.78)	7.37 (0.75)	5.87 (0.54)	4.45 (0.54)
E. C. (dSm ⁻¹ *)	10.25 (0.67)	12.50 (1.18)	12.6 (1.18)	8.97 (0.67)	0.95 (0.44)	0.24 (0.11)
Oxidizable carbon (%)	36.82 (3.02)	26.24 (2.29)	25.70 (2.57)	30.43 (3.04)	28.56 (3.12)	23.07 (3.11)
Total P (%)	1.03 (0.61)	1.13 (0.54)	0.96 (0.44)	0.95 (0.47)	0.93 (0.41)	0.95 (0.31)
Total K (%)	2.34 (1.27)	2.58 (1.27)	2.09 (1.78)	2.17 (1.28)	1.96 (1.21)	2.17 (1.22)
Total Ca (%)	2.04 (1.04)	5.08 (0.24)	4.39 (0.47)	5.84 (0.41)	1.45 (0.24)	6.61 (0.21)
Cr (mg kg ⁻¹)	7.86 (0.62)	5.44 (0.58)	6.30 (0.57)	5.45 (0.51)	8.80 (0.78)	7.00 (0.78)
Ni (mg kg ⁻¹)	3.18 (0.20)	6.24 (0.47)	3.24 (0.24)	4.41 (0.41)	3.00 (0.24)	4.70 (0.42)
Cu (mg kg ⁻¹)	49.29 (0.21)	93.80 (0.45)	27.52 (0.17)	52.38 (0.29)	54.50 (0.27)	44.70 (0.24)
Zn (mg kg ⁻¹)	253.41 (6.27)	361.33 (8.71)	214.80 (6.21)	355.78 (8.70)	293 (6.54)	377.00 (6.78)
Cd (mg kg ⁻¹)	0	0	0	0	0	0
Pb (mg kg ⁻¹)	0	0	0	0	0	0

*E. C. = electrical conductivity.

Table 4. Chemical composition of amended peat substrates and composted laying hen and broiler manures. Standard deviations are in parentheses.

Chemical composition	Broiler	Laying hen Stock piled	Laying hen Deep pit	Laying hen Deep litter	Peat Substrate 1	Peat Substrate 2
NH ₄ ⁺ -N (mg kg ⁻¹)	2510.51 (1.12)	5771.13 (1.71)	2019.95 (3.92)	605.99 (1.39)	58.93 (1.39)	61.26 (1.38)
NO ₃ ⁻ -N (mg kg ⁻¹)	472.31 (2.30)	755.50 (1.38)	119.80 (1.77)	449.00 (2.29)	1602.82 (1.05)	1311.58 (1.70)
Kjeldahl nitrogen (%)	3.60 (0.50)	3.00 (1.04)	3.10 (0.45)	4.01 (1.04)	0.98 (0.33)	1.14 (0.34)
pH (H ₂ O)	8.90 (0.33)	9.96 (0.33)	9.12 (0.28)	9.57 (0.24)	5.87 (0.54)	4.45 (0.54)
E. C. (dSm ⁻¹ *)	7.38 (1.20)	8.33 (1.14)	7.11 (1.12)	7.24 (1.12)	0.95 (0.44)	0.24 (0.11)
Oxidizable carbon (%)	29.92 (3.02)	22.20 (3.02)	26.41 (2.27)	23.92 (2.12)	28.56 (3.12)	23.07 (3.11)
Total P (%)	0.95 (0.47)	0.97 (0.47)	0.96 (0.48)	0.95 (0.44)	0.93 (0.41)	0.95 (0.31)
Total K (%)	2.18 (1.28)	2.37 (1.58)	2.08 (1.54)	2.14 (1.47)	1.96 (1.21)	2.17 (1.22)
Total Ca (%)	2.05 (0.31)	5.10 (0.54)	4.37 (0.48)	5.55 (0.58)	1.45 (0.24)	6.61 (0.21)
Cr (mg kg ⁻¹)	7.88 (0.68)	5.55 (0.67)	6.33 (0.57)	5.46 (0.47)	8.80 (0.78)	7.00 (0.78)
Ni (mg kg ⁻¹)	3.20 (0.32)	6.31 (0.34)	3.20 (0.24)	4.20 (0.27)	3.00 (0.24)	4.70 (0.42)
Cu (mg kg ⁻¹)	49.32 (0.47)	93.97 (0.57)	27.32 (0.18)	52.45 (0.17)	54.50 (0.27)	44.70 (0.24)
Zn (mg kg ⁻¹)	250.20 (6.20)	360.98 (6.21)	215.87 (5.87)	356.70 (5.64)	293 (6.54)	377.00 (6.78)
Cd (mg kg ⁻¹)	0	0	0	0	0	0
Pb (mg kg ⁻¹)	0	0	0	0	0	0

*E. C. = electrical conductivity

Statistical analyses

All data of germination tests were analysed using Statgraphics 5.1 software and an IBM personal computer. One-way ANOVA was performed to compare the mean of the results of the different treatments. When significant F values were obtained (0.05), the differences between individual means were tested using the least significant difference test.

RESULTS AND DISCUSSION

Seed germination and root growth

Mixtures of rising amounts of composted poultry manures with amended peat substrates Figures 1, 2, 3 and 4 show the germination index of *L. sativum* L. in relation to the

GERMINATION INDEX

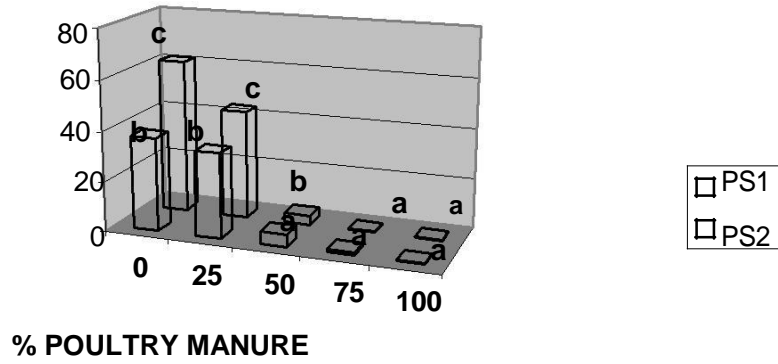


Figure 1. Germination index of cress (*Lepidium sativum*, L.) versus percentage of uncomposted poultry manure (laying hen, deep litter) in peat substrates 1 and 2. Different letters indicate significant differences between treatments ($p < 0.05$).

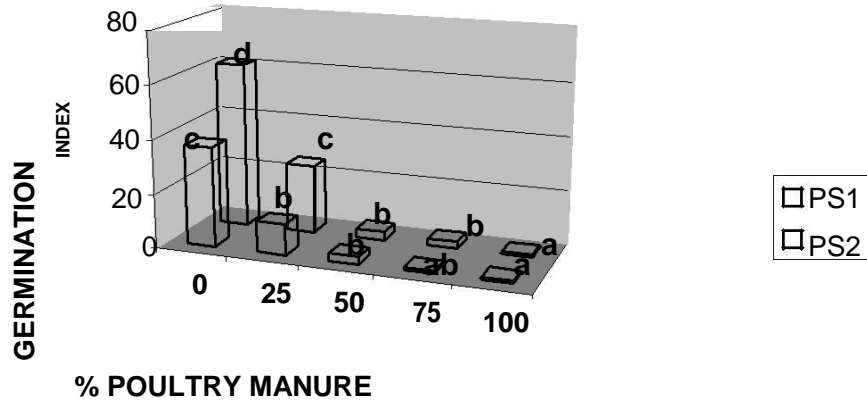


Figure 2. Germination index of cress (*Lepidium sativum*, L.) versus percentage of uncomposted poultry manure (laying hen, deep pit) in peat substrates 1 and 2. Different letters indicate significant differences between treatments ($p < 0.05$).

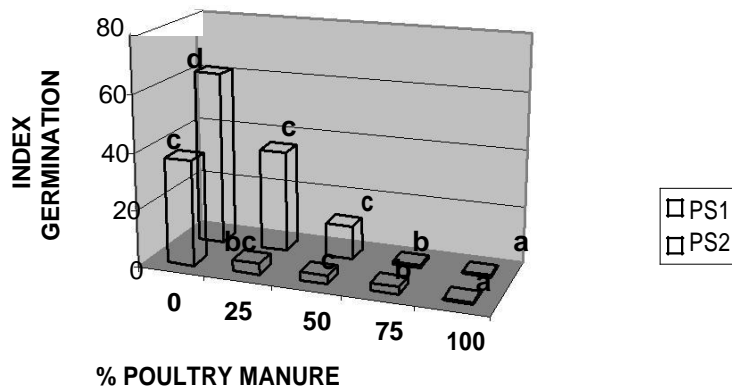


Figure 3. Germination index of cress (*Lepidium sativum*, L.) versus percentage of uncomposted poultry manure (laying hen, stock piled) in peat substrates 1 and 2. Different letters indicate significant differences between treatments ($p < 0.05$).

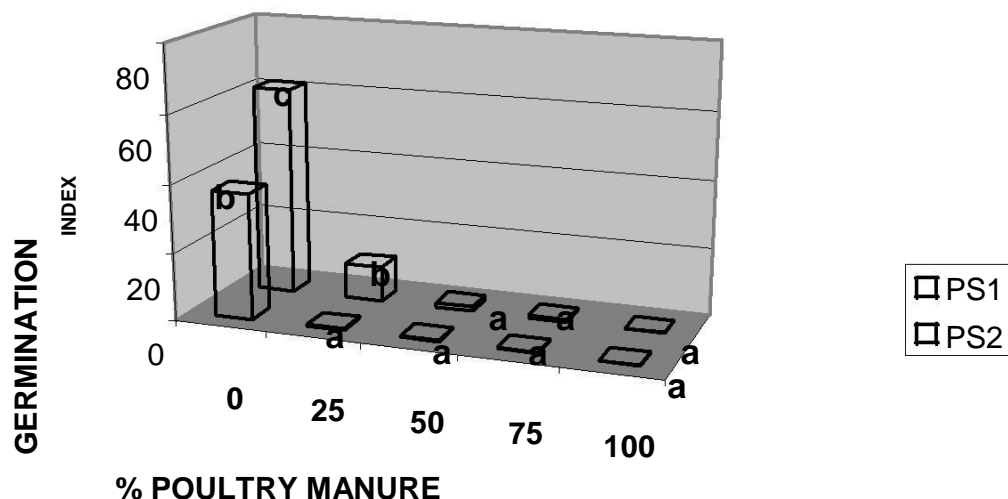


Figure 4. Germination index of cress (*Lepidium sativum*, L.) versus percentage of uncomposted poultry manure (broiler) in peat substrates 1 and 2. Different letters indicate significant differences between treatments ($p < 0.05$).

percentage of uncomposted poultry manures from laying hens (deep litter, deep pit, stock piled) and broilers, respectively, mixed with two amended peat substrates.

The highest GI rates were observed when extracts of peat without manure additions were used and peat substrate 2 produced better results than peat substrate 1. The observed inhibitory effect of substrate 1 extracts can be attributed to the high salinity: with EC 0.95 dsm^{-1} versus peat substrate 2 with EC 0.24 (Myers and Couper, 1989; Wollan et al., 1978; Roe et al., 1997; Wong et al., 2001).

When peat substrates and uncomposted manures were mixed, their extracts produced low GI rates, especially when the percentage of poultry manure was increased. The highest germination indices were reached in mixtures of peat substrate 2 with 25% uncomposted deep litter manure (43.55), followed by 25% uncomposted stock piled litter (35.85) and 25% uncomposted deep pit manure (25.48).

Figure 1 shows the results obtained for the germination index when the poultry manure was deep litter from laying hens. There was a higher germination index in the mixtures with peat substrate 2 (43.55) than in peat substrate 1 (33.99) with 25% manure added. Mixtures with 25% manure had got also a higher germination index with peat substrate 2 (25.48) and peat substrate 1 (11.48) than with the laying hen manure from deep pit manure (Figure 2) or than with the laying hen manure from stock piled, with a GI of 35.85 for peat substrate 2 and a GI of 2.43 for peat substrate 1 (Figure 3).

Figure 4 shows the results obtained for the germination index when the poultry manure was extracted from broiler manure. There was a higher germination index in the mixtures with peat substrate 2 (10.37) than with peat substrate 1 (0.52) with the 25% of manure added Zucconi et al. (1981) were considers that substrates with a GI near

to 50 are phytotoxin-free and, as a consequence, their application should not injure plants.

Mixtures of rising amounts of composted poultry manures with amended peat substrates

Figures 5, 6, 7 and 8 represent the germination index of *L. sativum* L. in relation to the percentage of composted laying hen (deep litter, deep pit, stock piled) and broiler manure with peat substrates 1 and 2. The GI of seeds germinating in extracts from mixtures of composted poultry manure with peat substrate was lower than that of seeds germinating in extracts from peat substrate only and the GI decreased even more when the percentage of poultry manure in the mixtures was increased. Composted laying hen manure from deep pit mixed with either of the two peat substrates, at rates of 25 - 50, did not present toxicity (Figure 6). Additions of 25 - 50% of composted layer hen manure (deep litter and stock piled) or broiler litter to the peat substrates were not considered phytotoxic (Figures 5, 7 and 8). Substrates that show a GIS > 100 could be considered as carrier of stimulating growth properties (Warman, 1999).

All Figures show the ANOVA results from different types of poultry manure. Means within each peat substrate followed by the same litter (s) are not significantly different ($p < 0.05$).

Chemical parameters before and after the composting process

Tables 3 and 4, show the chemical composition of the two amended peat substrates and the different composted and uncomposted poultry manures. The lower concentration of the oxidizable carbon, the inorganic

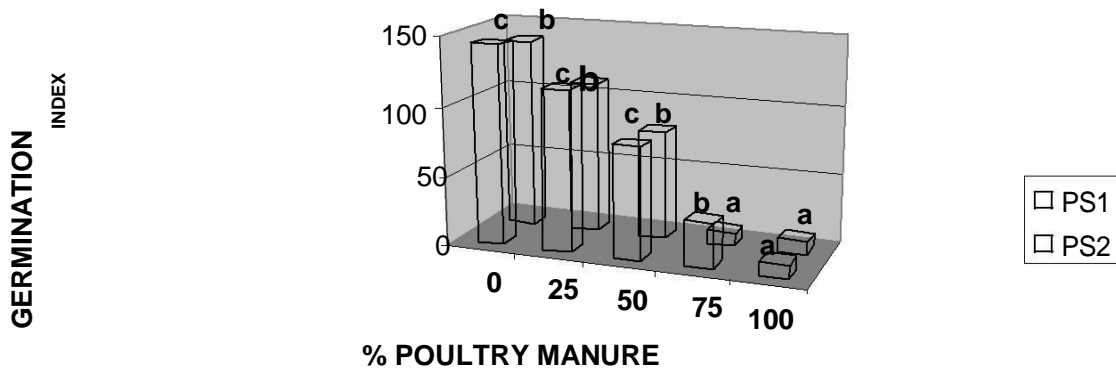


Figure 5. Germination index of cress (*Lepidium sativum*, L.) versus percentage of composted poultry manure (laying hen, deep litter) in peat substrates 1 and 2. Different letters indicate significant differences between treatments ($p < 0.05$).

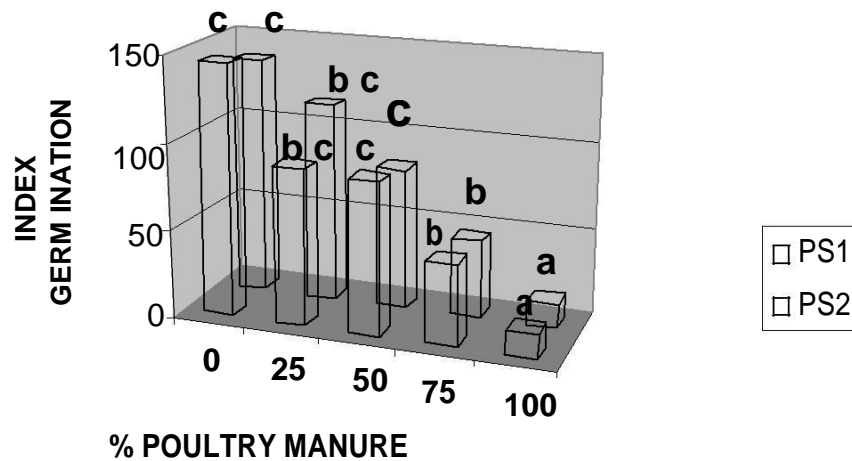


Figure 6. Germination index of cress (*Lepidium sativum*, L.) versus percentage of composted poultry manure (laying hen, deep pit) in peat substrates 1 and 2. Different letters indicate significant differences between treatments ($p < 0.05$).

nitrogen concentration too, was lower when the poultry manure was composted as was observed by Bernal et al. (1996). Fernández et al. (2007) who studied the organic matter (OM) in degraded agricultural soil amended with sewage sludges, reported that the loss of OM was greatest (76%) during the bio-oxidative stage, when the temperature and the microbial activity were high. After the bio-oxidative stage, during the maturation phase, the loss was lower (50%), which was indicative of compost stability. The lower concentration of $\text{NH}_4^+\text{-N}$ in composted manures can be attributed to its conversion to $\text{NO}_3^-\text{-N}$ and its volatilisation in NH_3 form as result of the high pH observed during the composting process.

The decreasing concentrations of $\text{NH}_4^+\text{-N}$ combined with increasing concentrations of $\text{NO}_3^-\text{-N}$ towards the end of the composting process of organic wastes, suggest

that the intensity of the biological decomposition has decreased and the compost is mature enough to be used in agriculture (Bernal et al., 1998).

The germination delay which was observed in some peat substrates treatments with uncomposted poultry manures indicated that the samples were phytotoxic for cress seeds. Wu et al. 2000 reported that the compost stability based on CO_2 evolution and its maturity based on seed germination, are indeed two different characteristics of compost quality. Generally, stability and maturity may be correlate (e.g. more stable compost tends to be more mature). However, due to variation in compost feedstock and composting processes, some stable compost may need more time to break down the phytotoxic substances and mature compost may have relative high respiration rate. As a result, both parameters

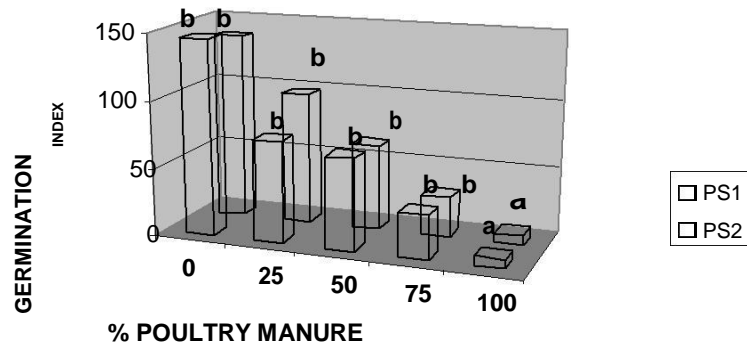


Figure 7. Germination index of cress (*Lepidium sativum*, L.) versus percentage of composted poultry manure (laying hen, stock piled) in peat substrates 1 and 2. Different letters indicate significant differences between treatments ($p < 0.05$).

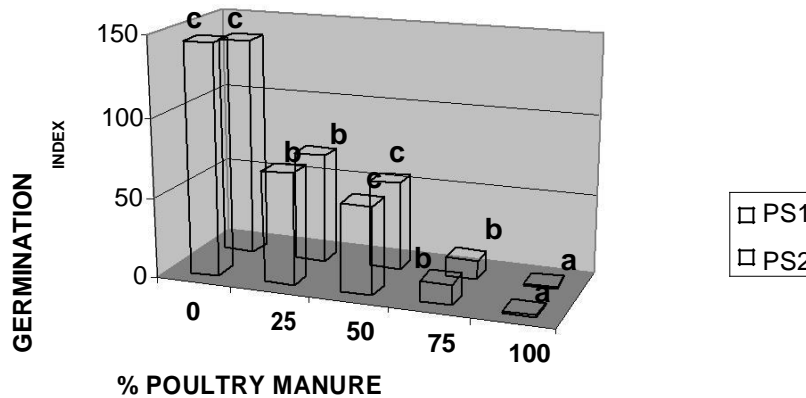


Figure 8. Germination index of cress (*Lepidium sativum*, L.) versus percentage of composted poultry manure (broiler) in peat substrates 1 and 2. Different letters indicate significant differences between treatments ($p < 0.05$).

are needed to assure high quality compost product. Another problem is the potentially phytotoxic nature of the organic wastes mainly as a result of a combination of several factors, such as their high salinity, and of any excess of ammonium ions (Table 3), organics compounds, or any fatty acids with low molecular weight they might carry. All of these can also inhibit seed germination (Wollan et al., 1978; Roe et al., 1997; Wong et al., 2001). Wu and Ma (2001) proved that heavy metals cause phytotoxicity and they can delay the maturation process, when the maximum levels of the heavy metals were higher than the maximum allowed in Europe for land-applicable wastes (Cd > 40, Cr > 1500, Cu > 1750, Ni > 450, Pb > 1200 and Zn > 4000 mgkg⁻¹). In our work the heavy metal contents of uncomposted and composted poultry manures (Tables 3 and 4) were below the thres-

hold, defined by the European Commission (1986) and the USEPA (1993). Although, the total heavy metal contents of the uncomposted and composted poultry manures were similar, Richards's et al. (1997) found reductions in the mobility of Ni and Pb and an increase in Cd and Cu mobility is as result of the composting process, whereas, Cr and Zn mobility remained relatively constant.

Conclusions

The results of the current work indicate the necessity to stabilize poultry manure before its application to agricultural soil, in order to avoid environmental problems and phytotoxicity. The following conclusions can be drawn

from this work:

- (i) The composting reduces phytotoxicity of poultry manure.
- (ii) The phytotoxicity appears to be mainly related to electrical conductivity and ammonium concentration.
- (iii) The Germination Index decreases with increasing concentrations of uncomposted and composted poultry manure.
- (iv) Uncomposted poultry manure always exhibits phytotoxicity.
- (v) Substrates that show a GIS > 100 could be considered as carrier of stimulating growth properties.
- (vi) Mixtures of composted laying hen manures from deep pit in rates of 25 - 50% with amended peat substrates do not seem to be phytotoxic.
- (vii) Mixtures of 25 - 50% composted poultry manure from stock piled, deep litter or broiler litter with amended peat substrates are safe for plant application.
- (viii) Composted poultry manure is a valuable source of organic matter, nitrogen, phosphorus and other nutrients.

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